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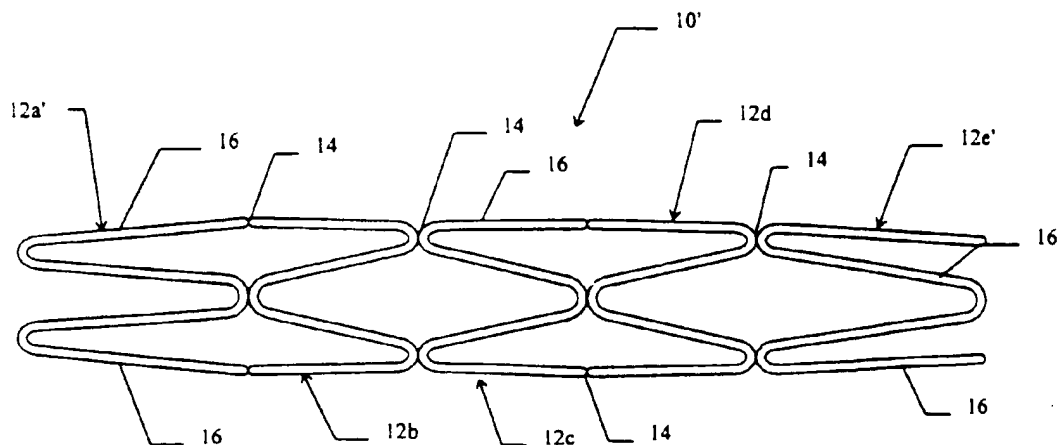
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(54) **Stent for supporting lumens in living tissue**

(57) The disclosure relates to a stent (10) for helping to hold open a lumen in a tubular body structure having at least one axial portion (12a to 12e), preferably an axial end portion (12a or 12e) that stents the surrounding portion of the tubular body structure to a lesser degree than

another axial portion (12c or 12d) of the stent. For example, the stent portion that stents to a lesser degree may be circumferentially weaker than the other stent portion, or it may recoil more than the other stent portion after the stent is applied by being circumferentially expanded and then released.



**Figure 3**

## Description

This invention relates to stents for supporting lumens in living tissue in order to help hold those lumens open. The lumen may be a blood vessel, a bile duct, or any other similar body conduit that is tending to improperly constrict as a result of disease or malfunction. The lumen may be a graft (whether natural or artificial) in any type of body conduit.

It is known to insert hollow tube-defining structures ("stents") into tubular body organs or structures such as blood vessels to help open and keep open those body structures. See Boneau U.S. patent 5,292,331 and Hillstead U.S. patent 5,135,536 for examples of metal stent structures. (These two references are hereby incorporated by reference herein.) Stents of these types are typically introduced into a blood vessel or other tubular body structure on the deflated balloon of a balloon catheter. When the stent is at the desired location in the tubular body structure, the balloon is inflated to circumferentially expand the stent. The balloon is then deflated and the catheter is withdrawn, leaving the circumferentially expanded stent in the tubular body structure, usually as a permanent prosthesis for helping to hold the tubular body structure open and prevent stenosis or restenosis of that body structure.

While stents and stent applications of the type described above have been found to work extremely well, there may be room for improvement (at least in some cases) in avoiding abrupt transitions between stented and unstented regions of a tubular body structure. Such abrupt transitions may trigger a body reaction at or near the transition. Avoiding abrupt transitions or reducing the abruptness of such transitions may therefore be more therapeutic.

In view of the foregoing, it is an object of this invention to provide improved structures and methods for stenting tubular body structures.

It is a more particular object of this invention to provide stent structures and methods which reduce the abruptness of the transitions between the stented region and the unstented regions in a tubular body structure in which the stent is employed.

These and other objects of the invention are accomplished in accordance with the principles of the invention by providing stent structures having at least one axial end portion which less strongly holds open or stents the surrounding portion of the tubular body structure in which the stent is being employed than a remaining portion of the stent holds open the portion of the tubular body structure that surrounds the remaining portion. Preferably both axial end portions of the stent are like the above-described end portion, with the above-described remaining portion being medial between the two axial end portions. The axial end portion or portions which less strongly hold open the tubular body structure can be provided in any of a large number of ways. For example, the axial end portion or portions can be made

circumferentially weaker (elastically or plastically) than other portions of the stent. (As is explained in more detail below, terms like "plastic" and "plastically" are used herein to mean any type of non-elastic (e.g., permanent) deformation.) Or the axial end portion or portions can be made to recoil somewhat more after circumferential expansion and release than other portions of the stent recoil.

Methods of making stents in accordance with the invention include forming first and second axially spaced, annular stent portions so that the first portion is circumferentially stronger (elastically or plastically) than the second portion. Alternatively, the methods of making stents in accordance with the invention may include forming first and second axially spaced annular stent portions so that the second portion has a higher yield strength than the first portion. The first portion is preferably formed as an axially medial portion of the stent, while the second portion is preferably formed as an axial end portion of the stent. A third annular axial portion of the stent may be formed similarly to the second portion, and is preferably formed as another axial end portion of the stent that is axially remote from the second portion.

Methods of using stents in accordance with the invention include inserting the stent into a tubular body structure, circumferentially expanding the stent, and then releasing the stent so that the tubular body structure can circumferentially recompress a circumferentially weaker, second annular axial portion of the stent more than it recompresses a circumferentially stronger, first annular axial portion of the stent. The weaker portion can be elastically or plastically weaker than the stronger portion. Alternatively, methods of using stents in accordance with the invention include inserting the stent into a tubular body structure, circumferentially expanding the stent, and then releasing the stent so that a second annular axial portion of the stent which has a relatively high yield strength springs back more from circumferential expansion than a first annular axial portion of the stent which has a relatively low yield strength.

Further features of the invention, its nature and various advantages will be more apparent from the following detailed description of the preferred embodiments with reference to the accompanying drawings.

FIG. 1 is a simplified isometric view of an illustrative embodiment of a stent constructed in accordance with this invention. FIG. 1 shows the stent prior to circumferential expansion.

FIG. 2 is a simplified elevational view of the stent of FIG. 1 after circumferential expansion and implantation in a tubular body structure.

FIG. 3 is another view similar to FIG. 2 showing another illustrative embodiment of the invention. Like FIG. 2, FIG. 3 shows the stent after circumferential expansion and implantation in a tubular body structure.

The above-mentioned Boneau and Hillstead patents, and the references cited in those patents, make it clear that stents can be constructed in many different

ways. The present invention is applicable to all known stent constructions, and it will be readily apparent from the following discussion of several exemplary constructions how the invention can be applied to any other type of stent construction.

An illustrative stent 10 made of metal is shown in FIG. 1. Stent 10 includes five sections 12a-e, each of which is made of an endless metal loop that has been bent so that it no longer lies in a plane (see, for example, the above-mentioned Boneau patent for more detail as to how each of sections 12 may be shaped). As the Boneau patent makes clear, each section 12 may have more undulations than are shown in FIG. 1 (and generally similar subsequent FIGS.), but the simplified depictions shown herein will be sufficient to illustrate the present invention. Although sections 12 may or may not be made of what would be regarded in some other arts as wire, the material of sections 12 is generally wire-like, and so the term "wire" is sometimes used herein to refer to such stent material. Axially adjacent sections 12 may be joined to one another as indicated at regions 14 (only representative ones of which have the reference number 14 in FIG. 1). These connections (if and to the extent present) may be made by welding, soldering, adhesive bonding, mechanical fastening, or in any other suitable way.

A typical technique for applying stents of the general type shown in FIG. 1 is to initially dispose the stent structure in a circumferentially compressed form (e.g., the form shown in FIG. 1) around a deflated balloon which is part of a balloon catheter. The catheter is then inserted axially into a tubular body structure to be stented until the balloon and stent are at the desired location along the body structure. Then the balloon is inflated to circumferentially expand the stent. Lastly, the balloon is deflated and the catheter is withdrawn, leaving the expanded stent behind in the body structure.

The deformation of the stent produced by the balloon as described above is at least partly permanent. (For convenience herein and in the appended claims, such permanent deformation will be referred to as "plastic". It will be understood that the terms "plastic", "plastically", or the like as used herein mean any type of non-elastic or permanent deformation, whether in the traditional materials science sense and therefore due to straining some portion of the stent material beyond its elastic limit, or as a result of any other property of the stent material or structure which results in the deformed stent taking a "set" which is different from its initial set. Correspondingly, the term "yield strength" or the like as used herein and in the appended claims means the point at which the stent structure or its material transitions from elastic to plastic deformation, as the term "plastic" is broadly defined above.) The balloon is strong enough to overcome the yield strength of the stent, but when the balloon is no longer radially supporting the stent, the surrounding tubular body structure does not exert enough radially inward force on the stent to take it back through

its yield point, at least not to the extent that the stent returns to its original diameter.

In accordance with the present invention, at least one axial end section 12a or 12e of stent 10 is made so that it holds open ("stents") the surrounding portion of the tubular body structure somewhat less strongly and/or somewhat less extensively than the remaining sections of the stent. In other words, at least one of stent sections 12a and 12e stents the surrounding portion of the tubular body organ to a lesser degree than other sections 12 of stent 10. This can be accomplished in many different ways. For example, the less strongly stenting axial end section 12a or 12e can be made from a material having a lower modulus of elasticity or spring force than the other sections. Then, after the stent has been circumferentially expanded and released, the axial end section 12a or 12e holds open its radially adjacent or surrounding portion of the tubular body structure less strongly and/or less extensively than the other sections of the stent hold open their radially adjacent or surrounding body structure portions. FIG. 2 shows how the stent of FIG. 1, constructed as has just been described, appears when circumferentially expanded and released in a tubular body structure. FIG. 2 illustrates the case in which both end sections 12a and 12e are made less strongly stenting than other sections of the stent.

The latter portion of the preceding paragraph describes making axial end section 12a or 12e elastically weaker than the other sections. A similar result can be achieved by making axial end section 12a or 12e plastically weaker (i.e., of lower yield strength) than other sections, so that after the stent has been implanted in a tubular body structure, the body structure can plastically recompress the weaker axial end section more than it plastically recompresses the other sections. For example, this can be done by using materials with different yield strengths for the various stent sections and/or by using a plastically weaker configuration or construction for end section 12a or 12e. The sections other than 12a or 12e may have sufficiently high yield strength that they are not plastically recompressed at all. In that case the tubular body structure only exceeds the lower yield strength of the relatively weak end section 12a or 12e. (It will be understood, of course, that the tubular body structure typically elastically recompresses all sections of the stent in addition to the above-described plastic deformation of (at least) end section 12a or 12e.) Although less strong than the other sections of the stent, end section 12a or 12e is nevertheless strong enough to hold open the tubular body structure to some degree more than it was open prior to stenting. Again, FIG. 2 shows how the stent of FIG. 1, constructed as described in this paragraph, appears when circumferentially expanded and released in a tubular body structure. As mentioned above, FIG. 2 illustrates the case in which both end sections 12a and 12e are made less strongly stenting than other sections of the stent.

Stent sections having different yield strengths can

be made in many different ways. For example, the various stent sections can be made of different materials which have different yield strengths. In the case of metal stents, the various sections can be annealed differently or to different degrees to give them different yield strengths. In particular, a lower yield strength axial end section 12a or 12e is annealed more than other sections. In the case of stents made of precipitation hardening materials, the various sections can be precipitation hardened by different amounts to give them different yield strengths. In particular, a lower yield strength end section 12a or 12e is precipitation hardened less than other sections. Annealing and precipitation hardening are further discussed in connection with the next illustrative embodiments to be described. As an alternative to using different materials or differently treated materials to produce stent section 12 with different yield strengths, the configuration or construction of the various sections can be made different so that end section 12a or 12e yields more easily than other sections. For example, end section 12a or 12e can be made from thinner wire or can be made axially longer so that it is not strong enough to escape some plastic re-deformation when it is released by the balloon and therefore circumferentially recompressed by the tubular body structure.

As another example of stents in accordance with this invention, axial end section 12a or 12e may be made with a higher yield strength than the other sections. Then, when the stent is circumferentially expanded and released, the higher yield strength end section 12a or 12e tends to recoil from the circumferential expansion somewhat more than the lower yield strength sections. The higher yield strength end section 12a or 12e therefore holds open the surrounding portion of the stented body structure less extensively than the lower yield strength sections hold open their surrounding portion of the body structure. Once again, this is shown in FIG. 2 (for the case in which both axial end sections 12a and 12e have higher yield strength than medial sections 12b-d) by the somewhat smaller average diameters of axial end sections 12a and 12e as compared to the diameters of the medial sections 12b-d. In embodiments of this kind, even the lower yield strength sections are preferably strong enough to avoid plastic recompression by the tubular body structure when the balloon is deflated and removed.

A difference in material that can be used to produce an end section of higher yield strength may be just a different treatment of the material. In the case of metal stents, for example, the axial end section may be annealed less than other sections of the stent. Precipitation hardening materials may be used to produce an effect somewhat opposite to annealing. With such materials, the longer the material is "aged" (i.e., held at an elevated temperature that causes precipitation of hardening constituents in the material) the higher the yield strength of the material becomes. Thus axial end section 12a or 12e may be the aged section (or the section

that is aged more than the other sections) to give it a higher yield strength. The result is similar to that described above in connection with FIG. 2.

Other ways to produce less strongly stenting axial end sections 12a or 12e in accordance with this invention include making axial end section 12a or 12e from thinner and therefore less strong wire than the other sections. Thus axial end section 12a or 12e may be elastically and/or plastically recompressed by the tubular body structure more than other sections are elastically and/or plastically recompressed by that body structure. Or axial end section 12a or 12e may be made with a different configuration, which is selected to be circumferentially weaker (plastically or elastically) than the other sections. FIG. 3 shows an example of this approach, in which both axial end sections 12a' and 12e' are made longer than sections 12b-d. The longer segments 16 of wire in sections 12a' and 12e' are more easily deflected, thereby giving axial end sections 12a' and 12e' less circumferential strength than the other sections 12b-d. Varying the number of undulations from section to section is another way to provide the various sections with different stenting strengths. Varying the structure in a tubular slotted stent design or the structural shape in other stent designs can also be used to produce end sections which either spring back more after circumferential expansion and release, or which provide less strength of support, or both.

As has been alluded to, FIGS. 2 and 3 explicitly illustrate the point that both axial end sections 12a and 12e (now and hereafter used as generic references for the axial end sections in any of the depicted embodiments) can be made as described above for either axial end section. Indeed, the presently preferred embodiments are those in which both axial end sections 12a and 12e are made less strongly stenting than the remaining medial sections 12b-d.

By providing at least one and preferably two axial end sections that are less strongly stenting than the other sections, the transition or transitions between the stented and unstented portions of the tubular body structure are made less abrupt. This helps make the stent more acceptable to the body and therefore less likely to produce an adverse reaction in the body.

It will be understood that the principles described above are equally applicable to all other types of stent constructions. For example, these principles can be applied to tubular slotted stents, to tubular braided wire stents, to self-expanding stents, to thermally expanding stents, to non-metallic (e.g., polymeric, ceramic, and/or composite) stents, etc. It will be readily apparent to those skilled in the art how the principles of this invention can be applied to all of these various types of stents. For example, weaker end sections can be produced in polymeric and/or ceramic stents by variations in material properties, material condition, and/or structural shape.

As another example of modifications within the scope of this invention, stent sections with more than

two different degrees of stenting can be used if desired. Thus the degree of stenting of sections 12b and 12d in FIG. 1 could be greater than the degree of stenting of sections 12a and 12e, but less than the degree of stenting of section 12c, to provide a stent which gradually increases in degree of stenting (i.e., circumferential strength and/or extent) from either axial end toward the center. The number of sections 12 shown in the drawings is merely illustrative, and any number of sections can be used. The sections may be connected to one another or not, as desired. The sections need not be discrete, but could instead be portions of one continuous structure whose degree of stenting varies stepwise or gradually (e.g., continuously) along its axial length. Thus it will be understood that references herein to stent portions or sections being "axially spaced" from one another do not require these stent portions or sections to be at some axial distance from one another. Rather, they can be immediately adjacent to one another if desired. "Axially spaced" merely means that the stent portions or sections form a succession along the longitudinal axis of the stent or the tubular body structure in which the stent is used.

#### Claims

1. A stent for helping to hold open a lumen in a tubular body structure comprising:
  - a first axial stent portion which is radially adjacent to a first axial portion of the tubular body structure; and
  - a second axial stent portion which is radially adjacent to a second axial portion of the tubular body structure, said first axial stent portion being adapted to stent said first axial portion of the tubular body structure to a greater degree than said second axial stent portion is adapted to stent said second axial portion of the tubular body structure.
2. The stent defined in claim 1 wherein said second axial stent portion is adjacent to an axial end of said stent and said first axial stent portion is axially spaced from axial ends of said stent.
3. The stent defined in claim 2 further comprising:
  - a third axial stent portion which is radially adjacent to a third axial portion of the tubular body structure, said third stent portion being adapted to stent said third axial portion of the tubular body structure to a lesser degree than said first axial stent portion is adapted to stent said first axial portion of the tubular body structure, said third axial stent portion being adjacent to an axial end of said stent that is remote from the axial end of said stent that said second axial stent portion is adjacent to.
4. The stent defined in claim 1 wherein said second axial stent portion is circumferentially weaker than said first axial stent portion.
5. The stent defined in claim 4 wherein said second axial stent portion is circumferentially elastically weaker than said first axial stent portion.
6. The stent defined in claim 4 wherein said second axial stent portion is circumferentially plastically weaker than said first axial stent portion.
7. The stent defined in claim 4 wherein said second axial stent portion is made circumferentially weaker by forming it using a material that is weaker than a material from which said first axial stent portion is formed.
8. The stent defined in claim 7 wherein the material of said second axial stent portion has a lower modulus of elasticity than the material of said first axial stent portion.
9. The stent defined in claim 7 wherein the material of said second axial stent portion has a lower yield strength than the material of said first axial stent portion.
10. The stent defined in claim 9 wherein the material of said first and second axial stent portions is metal which has been annealed to a greater degree in said second axial stent portion than in said first axial stent portion.
11. The stent defined in claim 9 wherein the material of said first and second stent portions is precipitation hardening material which has been precipitation hardened to a greater degree in said first axial stent portion than in said second axial stent portion.
12. The stent defined in claim 4 wherein said second axial stent portion is made circumferentially weaker by forming it using a member that has a smaller cross section than a member from which said first axial stent portion is formed.
13. The stent defined in claim 4 wherein said second axial stent portion is made circumferentially weaker by forming it using members that are longer between connections to other members than members from which said first axial stent portion is formed.
14. The stent defined in claim 1 wherein said second axial stent portion has a higher yield strength than said first axial stent portion.
15. The stent defined in claim 14 wherein said stent is

- disposed in said lumen by being circumferentially expanded after positioning in said lumen, and wherein, as a result of its higher yield strength, said second axial stent portion recoils from circumferential expansion to a greater degree than said first axial stent portion recoils from circumferential expansion.
16. The stent defined in claim 1 wherein said second axial stent portion is formed from a material having a higher yield strength than material from which said first axial stent portion is formed.
17. The stent defined in claim 16 wherein the material of said stent is metal which has been annealed to a greater degree in said first axial stent portion than in said second axial stent portion.
18. The stent defined in claim 16 wherein the material of said stent is precipitation hardening material which has been precipitation hardened to a greater degree in said second axial stent portion than in said first axial stent portion.
19. A stent for helping to hold open a lumen in a tubular body structure comprising:
- a first axial stent portion which is radially adjacent to a first axial portion of the tubular body structure; and
  - a second axial stent portion which is radially adjacent to a second axial portion of the tubular body structure, said second axial stent portion being circumferentially weaker than said first axial stent portion.
20. The stent defined in claim 19 wherein said second axial stent portion is adjacent to an axial end of said stent and said first axial stent portion is axially spaced from axial ends of said stent.
21. The stent defined in claim 20 further comprising:
- a third axial stent portion which is radially adjacent to a third axial portion of the tubular body structure, said third axial stent portion being circumferentially weaker than said first axial stent portion, said third axial stent portion being adjacent to an axial end of said stent that is remote from the axial end of said stent that said second axial stent portion is adjacent to.
22. The stent defined in claim 20 wherein said second axial stent portion is circumferentially elastically weaker than said first axial stent portion.
23. The stent defined in claim 20 wherein said second axial stent portion is circumferentially plastically weaker than said first axial stent portion.
24. The stent defined in claim 20 wherein said second axial stent portion is made circumferentially weaker by forming it using a material that is weaker than a material from which said first axial stent portion is formed.
25. The stent defined in claim 24 wherein the material of said second axial stent portion has a lower modulus of elasticity than the material of said first axial stent portion.
26. The stent defined in claim 24 wherein the material of said second axial stent portion has a lower yield strength than the material of said first axial stent portion.
27. The stent defined in claim 26 wherein the material of said first and second axial stent portions is metal which has been annealed to a greater degree in said second axial stent portion than in said first axial stent portion.
28. The stent defined in claim 26 wherein the material of said first and second stent portions is precipitation hardening material which has been precipitation hardened to a greater degree in said first axial stent portion than in said second axial stent portion.
29. The stent defined in claim 20 wherein said second axial stent portion is made circumferentially weaker by forming it using a member that has a smaller cross section than a member from which said first axial stent portion is formed.
30. The stent defined in claim 20 wherein said second axial stent portion is made circumferentially weaker by forming it using members that are longer between connections to other members than members from which said first axial stent portion is formed.
31. A stent for helping to hold open a lumen in a tubular body structure comprising:
- a first axial stent portion which is radially adjacent to a first axial portion of the tubular body structure; and
  - a second axial stent portion which is axially adjacent to a second axial portion of the tubular body structure, said second axial stent portion having a greater yield strength than said first axial stent portion so that when said stent is circumferentially expanded and then released, said second axial stent portion recoils from circumferential expansion to a greater degree than said first axial stent portion.
32. The stent defined in claim 31 wherein said second

axial stent portion is adjacent to an axial end of said stent and said first axial stent portion is axially spaced from axial ends of said stent.

33. The stent defined in claim 32 further comprising:

a third axial stent portion which is radially adjacent to a third axial portion of the tubular body structure, said third axial stent portion having a greater yield strength than said first axial stent portion, said third axial stent portion being adjacent to an axial end of said stent that is remote from the axial end of said stent that said second axial stent portion is adjacent to.

34. The stent defined in claim 32 wherein the material of said stent is metal which has been annealed to a greater degree in said first axial stent portion than in said second axial stent portion.

35. The stent defined in claim 32 wherein the material of said stent is precipitation hardening material which has been precipitation hardened to a greater degree in said second axial stent portion than in said first axial stent portion.

36. The method of implanting an axially extending annular stent in a tubular body structure to radially support the tubular body structure, said stent having first and second axially spaced portions such that said first portion is circumferentially stronger than said second portion, said method comprising the steps of:

inserting said stent in said tubular body structure;

circumferentially expanding said stent; and releasing said stent so that it must support itself and said tubular body structure and so that said tubular body structure is able to circumferentially recompress said second portion more than said first portion.

37. The method defined in claim 36 further comprising the step of:

forming said first portion so that it is circumferentially elastically stronger than said second portion.

38. The method defined in claim 36 further comprising the step of:

forming said first portion so that it is circumferentially plastically stronger than said second portion.

39. The method defined in claim 36 further comprising the step of:

forming said first portion from a material that is stronger than a material from which said second

portion is formed.

40. The method defined in claim 39 wherein said forming step comprises the step of:

employing for said first portion a material having a higher modulus of elasticity than the material from which said second portion is formed.

41. The method defined in claim 39 wherein said forming step comprises the step of:

employing for said first portion a material having a higher yield strength than the material from which said second portion is formed.

42. The method defined in claim 41 wherein the material of said stent is metal, and wherein said employing step comprises the step of:

annealing the metal of said second portion to a greater degree than the metal of said first portion is annealed.

43. The method defined in claim 41 wherein the material of said stent is precipitation hardening material, and wherein said employing step comprises the step of:

precipitation hardening the material of said first portion to a greater degree than the material of said second portion is precipitation hardened.

44. The method defined in claim 36 further comprising the step of:

forming said first portion from a member having a larger cross section than a member from which said second portion is formed.

45. The method defined in claim 36 further comprising the step of:

forming said first portion from members that are shorter between connections to other members than members from which said second portion is formed.

46. The method defined in claim 36 wherein said stent also has a third portion axially spaced from said second portion by said first portion, said first portion also being circumferentially stronger than said third portion, and wherein said releasing step comprises the step of releasing said third portion so that said tubular body structure is able to circumferentially recompress said third portion more than said first portion.

47. The method of implanting an axially extending annular stent in a tubular body structure to radially support the tubular body structure, said stent having first and second axially spaced portions such that said second portion has a higher yield strength than said first portion, said method comprising the steps

of:

inserting said stent in said tubular body structure;  
circumferentially expanding said stent; and  
releasing said stent so that it must support itself  
and said tubular body structure and so that said  
second portion springs back more from circumferential expansion than said first portion.

48. The method defined in claim 47 wherein said stent is made of metal, and wherein said method further comprises the step of:

forming said first portion from metal that is annealed to a greater degree than the metal from which said second portion is formed.

49. The method defined in claim 47 wherein said stent is made of precipitation hardening material, and wherein said method further comprises the step of:

forming said second portion from material that is precipitation hardened to a greater degree than the material from which said first portion is formed.

50. The method defined in claim 47 wherein said stent also has a third portion axially spaced from said second portion by said first portion, said third portion also having a higher yield strength than said first portion, and wherein said releasing step comprises the step of releasing said third portion so that said third portion springs back more from circumferential expansion than said first portion.

51. The method of making an annular, axially extending stent for insertion into a tubular body structure to radially support the tubular body structure, said method comprising the steps of:

forming a first annular axial portion of said stent so that said first portion is circumferentially relatively strong; and

forming a second annular axial portion of said stent so that said second portion is circumferentially relatively weak, said second portion being axially spaced from said first portion.

52. The method defined in claim 51 wherein said first portion is formed as an axially medial portion of said stent, and wherein said second portion is formed as an axial end portion of said stent.

53. The method defined in claim 52 further comprising the step of:

forming a third annular axial portion of said stent so that said third portion is circumferentially relatively weak, said third portion being an axial end portion which is axially remote from said second portion.

54. The method defined in claim 51 wherein said forming steps include the step of:

forming said first portion so that it is circumferentially elastically stronger than said second portion.

55. The method defined in claim 51 wherein said forming steps include the step of:

forming said first portion so that it is circumferentially plastically stronger than said second portion.

56. The method defined in claim 51 wherein said forming steps include the step of:

employing for said second portion a material that is weaker than a material from which said first portion is formed.

57. The method defined in claim 56 wherein said employing step comprises the step of:

producing said second portion from a material that has a lower modulus of elasticity than the material from which said first portion is formed.

58. The method defined in claim 56 wherein said employing step comprises the step of:

producing said second portion from a material that has a lower yield strength than the material from which said first portion is formed.

59. The method defined in claim 58 wherein the material of said first and second portions is metal, and wherein said producing step comprises the step of: annealing said second portion to a greater degree than said first portion is annealed.

60. The method defined in claim 58 wherein the material of said first and second portions is precipitation hardening material, and wherein said producing step comprises the step of:

precipitation hardening said first portion to a greater degree than said second portion is precipitation hardened.

61. The method defined in claim 51 wherein said forming steps include the step of:

employing for said second portion a member having a smaller cross section than a member from which said first portion is formed.

62. The method defined in claim 51 wherein said forming steps include the step of:

employing for said second portion members that are longer between connections to other members than members from which said first portion is formed.

63. The method of making an annular, axially extending



stent for insertion into a tubular body structure, said method comprising the steps of:

forming a first annular axial portion of said stent  
so that said first portion has a relatively low 5  
yield strength; and  
forming a second annular axial portion of said  
stent so that said second portion has a relative-  
ly high yield strength, said second portion being  
axially spaced from said first portion. 10

64. The method defined in claim 63 wherein said first  
portion is formed as an axially medial portion of said  
stent, and wherein said second portion is formed as  
an axial end portion of said stent. 15

65. The method defined in claim 64 further comprising  
the step of:  
forming a third annular axial portion of said  
stent so that said third portion has relatively high 20  
yield strength, said third portion being an axial end  
portion which is axially remote from said second  
portion.

66. The method defined in claim 63 wherein said first 25  
and second portions are formed from metal, and  
wherein said forming steps include the step of:  
annealing said first portion to a greater degree  
than said second portion is annealed. 30

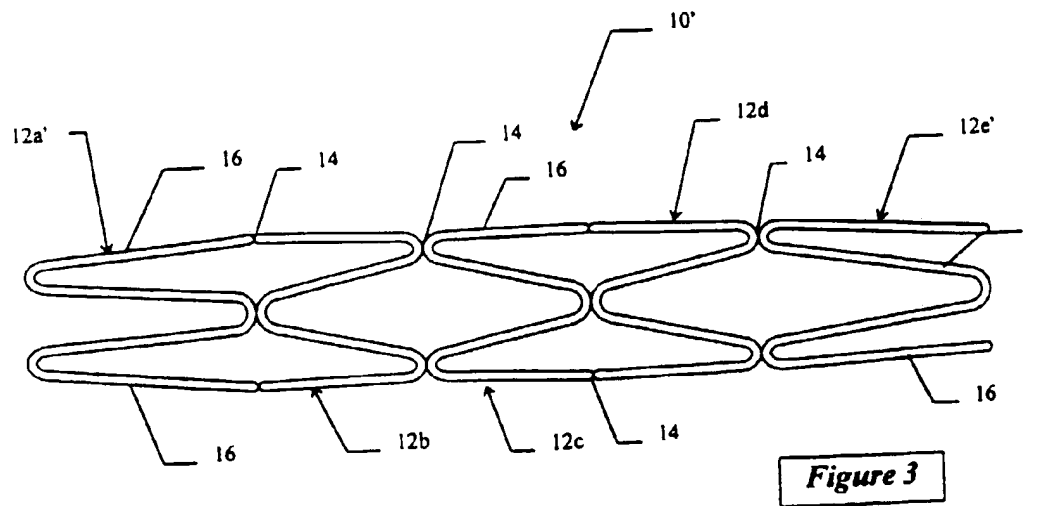
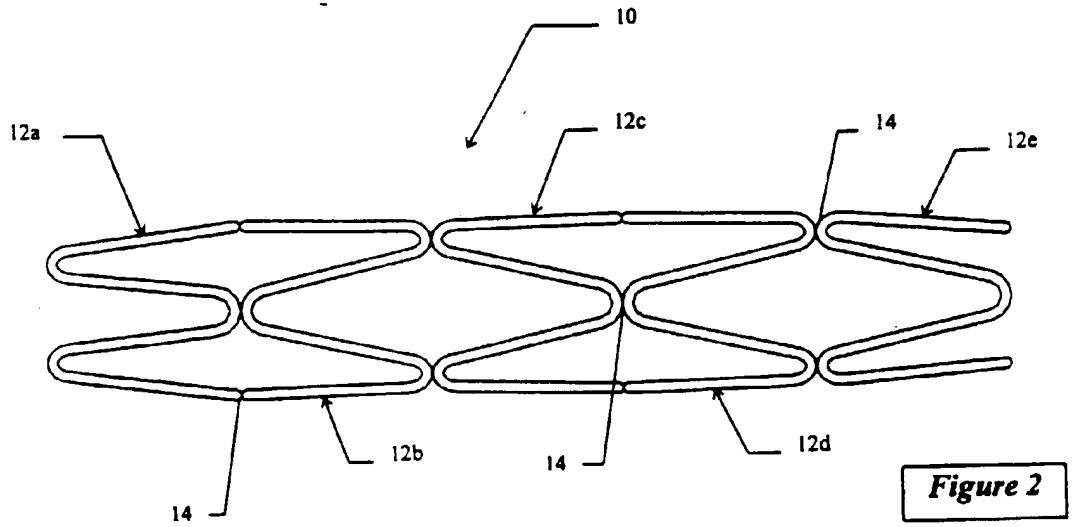
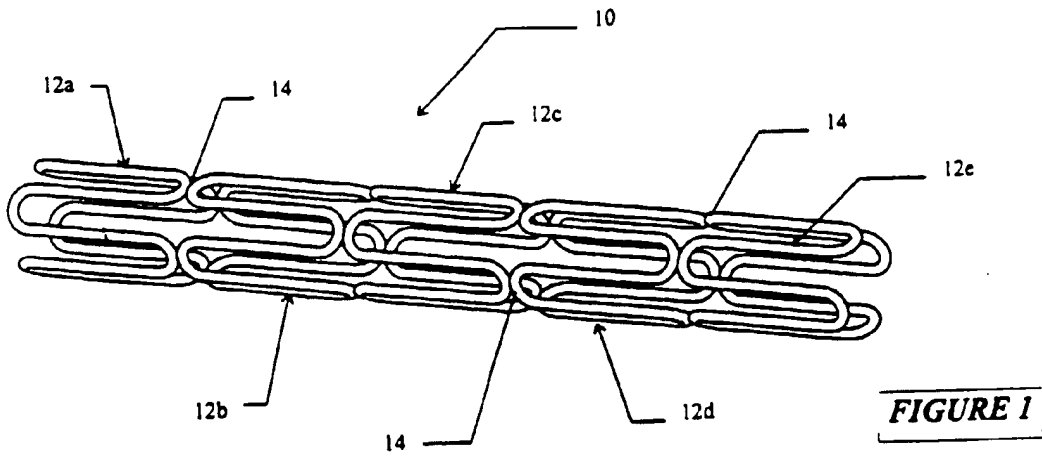
67. The method defined in claim 63 wherein said first  
and second portions are formed from precipitation  
hardening material, and wherein said forming steps  
include the step of:  
precipitation hardening said second portion to 35  
a greater degree than said first portion is precipita-  
tion hardened.

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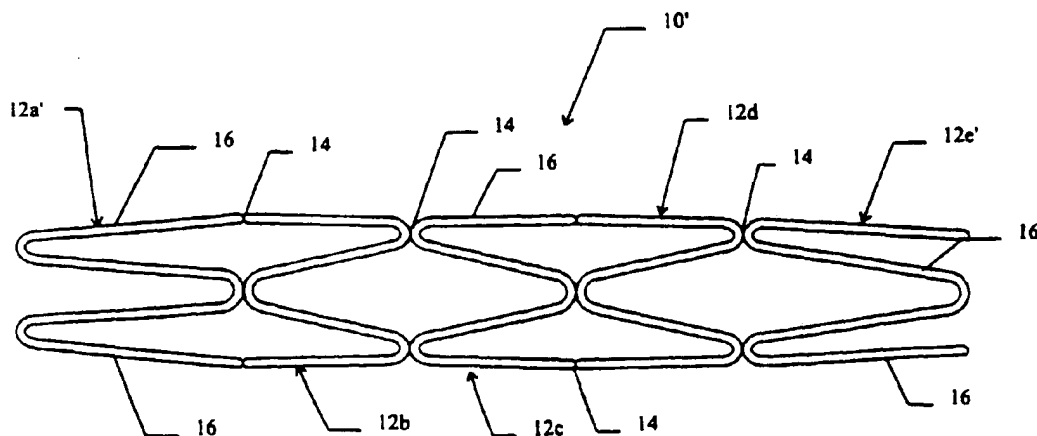
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(54) **Stent for supporting lumens in living tissue**

(57) The disclosure relates to a stent (10) for helping to hold open a lumen in a tubular body structure having at least one axial portion (12a to 12e), preferably an axial end portion (12a or 12e) that stents the surrounding portion of the tubular body structure to a lesser degree than

another axial portion (12c or 12d) of the stent. For example, the stent portion that stents to a lesser degree may be circumferentially weaker than the other stent portion, or it may recoil more than the other stent portion after the stent is applied by being circumferentially expanded and then released.



**Figure 3**



European Patent  
Office

# PARTIAL EUROPEAN SEARCH REPORT

Application Number

which under Rule 45 of the European Patent Convention EP 97 30 1681 shall be considered, for the purposes of subsequent proceedings, as the European search report

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X	WO 95 32757 A (NITINOL MEDICAL TECHNOLOGIES I) 7 December 1995	1,2,4-6, 9,10,12, 14-17, 19, 22-27, 29,31, 63,66	A61F2/06
A	* page 8, line 3 - line 19; figures 4,10 * * page 14, line 20 - page 15, line 20 * * page 16, line 6 - line 27 *	51,52, 54-56, 58,59,61	
X	WO 95 18585 A (BLANC LOUIS ;MICROFIL IND SA (CH)) 13 July 1995	1-5,13, 19-22, 30, 51-54,62	
A	* page 6, line 1 - line 25; figures * --- -/--	31-33, 63-65	
			TECHNICAL FIELDS SEARCHED (Int.Cl.6)
			A61F
INCOMPLETE SEARCH			
<p>The Search Division considers that the present application, or one or more of its claims, does/do not comply with the EPC to such an extent that a meaningful search into the state of the art cannot be carried out, or can only be carried out partially, for these claims.</p> <p>Claims searched completely :</p> <p>Claims searched incompletely :</p> <p>Claims not searched :</p> <p>36-50</p> <p>Reason for the limitation of the search:</p> <p>Article 52 (4) EPC - Method for treatment of the human or animal body by surgery</p>			
Place of search		Date of completion of the search	Examiner
THE HAGUE		24 August 1998	Neumann, E
CATEGORY OF CITED DOCUMENTS			
<p>X : particularly relevant if taken alone</p> <p>Y : particularly relevant if combined with another document of the same category</p> <p>A : technological background</p> <p>O : non-written disclosure</p> <p>P : intermediate document</p>		<p>T : theory or principle underlying the invention</p> <p>E : earlier patent document, but published on, or after the filing date</p> <p>D : document cited in the application</p> <p>L : document cited for other reasons</p> <p>&amp; : member of the same patent family, corresponding document</p>	

EPO FORM 1503 03/82 (P04C07)

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EPO FORM 1503 03.02 (P04C10)

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